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Indian Standard

CONDUCTIVE CLOTHING FOR LIVE WORKING AT A NOMINAL VOLTAGE UP TO 800 kV AC

UDC 621·315 — 783 : 614·895·5

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

July 1993 **Price Group 11**

Tools and Equipment for Live Working Sectional Committee, ET 36

NATIONAL FOREWORD

This Indian Standard which is identical with IEC Pub 895 (1987), issued by the International Electrotechnical Commission was adopted by the Bureau of Indian Standards on the recommendations of the Tools and Equipment for Live Working Sectional Committee (ET 36) and approval of the Electrotechnical Division Council.

The text of IEC Standard has been approved as suitable for publication as Indian Standard without deviations. In the Indian context, the National Committee, ET 36, has however decided to add the following line as first para to clause 3.8.4 : "The weight of hotline suit shall be less than 1 kg".

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their place are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC Pub 50 (151) (1978)	IS 1885 (Part 74) : 1993 Electrotechnical vocabulary: Part 74 Electrical and magnetic devices	Identical
IEC Pub 456 (1974)	IS 6390 : 1983* Domestic electric clothes washing machines	Not fully equivalent
ISO 3290 (1975)	IS 2898 : 1976 Steel balls for rolling bearings (*first revision*)	Technically equivalent

The concerned technical committee has reviewed the provisions of IEC Pub 212 (1971) and ISO 479 (1975) referred in this adopted standard and has decided that they are acceptable for use in conjunction with this standard.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Only the English language text in the International Standard has been retained while adopting it in this Indian Standard.

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*This Indian Standard is under revision to make it technically equivalent with the IEC publication.

Indian Standard

CONDUCTIVE CLOTHING FOR LIVE WORKING AT A NOMINAL VOLTAGE UP TO 800 kV AC

INTRODUCTION

The conductive clothing by the assembly of its different components should constitute an electrically continuous coverall, surrounding the worker with the possible exception of his face. However the worker can be protected by a face shield electrically connected to the suit itself.

If press studs, zip fasteners, hooks and eyes or any other method of fastening are used in the assembly of the complete suit, care should be taken to ensure that the electrical conductivity of the suit is not impaired.

The conductive clothing (complete assembly) should be electrically connected to the conductor or the conductive part on which the live working has to be carried out. This connection shall be made by a conductive braid fixed at one of its extremities to the conductive suit and at the other by a special clamp.

SECTION ONE — GENERAL

1. Scope

This standard is applicable to conductive clothing worn by electrical workers during live working (especially bare-hand working) at a nominal voltage level up to 800 kV a.c.

It is applicable to suit, gloves or mitts, hoods, shoes and socks.

The corresponding d.c. values are under consideration.

2. Terminology (see Appendix B)

Conductive material

Material composed of metallic threads or non-metallic conductive substances and natural or synthetic threads closely woven or knitted.

Connecting braid

Special conductive braid to connect the conductive suit to the live metal working point.

The connecting braid is equipped at one of its extremities with a connection system to the suit; the other extremity of the braid is equipped with a special clamp.

Hood

Part of the clothing covering the head.

Face shield

Part covering the worker's face. It can be a synthetic and metallized shield having good optical and anti-U.V. qualities, or consisting of a conductive net.

SECTION TWO — TECHNICAL REQUIREMENTS

3. Technical requirements on components

The material used shall have the following properties:

3.1 *Flame retardancy*

Placed in contact with a flame or a fire (e.g. an electric arc), the material shall be constituted to prevent the fire from spreading. This quality shall be checked as indicated in Sub-clause 4.1.

3.2 *Wear resistance*

The conductive clothing shall be resistant to abrasion and to tearing.

As special tests to check these qualities are difficult to set up and to perform, the satisfaction of the wearer and the life duration of the cloth will be the only elements to consider.

3.3 *Electrical resistance*

This quality can be considered as a basic element which determines the current carrying capability and the spark discharge properties.

The only direct consequence for a worker of the correct value of electrical resistance, is the low potential difference between two points of the cloth in contact with the skin and is consequently an element of comfort.

3.4 *Current-carrying capability*

During the worker's travel to his working position (from the metallic structure of the tower or from the ground in an aerial device) and at the moment of his connection to the live conductor, capacitive currents flow through his clothing. These can be significant and it is necessary for the suit to be able to conduct them without damage (heating, smoke...).

This capability will be checked as indicated in Sub-clause 4.3.

3.5 *Screening efficiency*

Material must have a screening efficiency better than 40 dB.

Screening efficiency of a conductive fabric is defined by the ratio of energy that would be received by a body without a screen to energy received by the same body screened by the conductive fabric. A ratio of two voltages measured in these conditions is used to calculate screening efficiency of the conductive fabric.

3.6 *Cleaning requirements*

To ensure that the screening efficiency and flame retardant properties of the clothing do not deteriorate excessively after repeated cleaning, the clothing shall be subjected to 10 wash-dry cycles and/or 10 dry-cleaning cycles. The screening effect and flame retardant properties shall still meet the specified requirements after the tests.

3.7 *Spark discharge protection*

To provide protection from spark discharges directly to the worker, the spacing between any individual adjacent conducting components in the fabric (except for face shield) shall not exceed 5 mm under all normal wearing conditions including stretching (such as at the elbows or knees).

3.8 *Requirements on:*

3.8.1. *Gloves and socks*

The resistance of gloves and socks shall be low enough for the maximum expected current flow through them not to be perceptible to the worker. This resistance shall have a maximum value of 100 Ω for gloves and 10 Ω for socks, when measured using the specified electrodes.

3.8.2 *Footwear*

The footwear resistance shall be low enough so that if the footwear is used alone, without conductive clothing, the voltage drop across the footwear, due to the induced current in a person in the highest expected field strength, will not result in an annoying discharge. The resistance shall have a maximum value of 500 Ω, when measured using the specified electrodes. If conductive socks are used, the shoes may be of a normal type without special conducting properties.

3.8.3 *Hood and face shield*

A conductive hood is necessary to provide screening effect.

It may be completed especially for very high voltages by a facial conductive shield. If no face shield is provided, protective flaps, conductive visor and the shape of the hood, shall ensure face protection. A bond between hood, facial shield and suit shall be provided.

3.8.4 *Clothing (complete assembly)*

Additional tests (Sub-clause 5.6) shall be carried out on the complete assembly to prove the actual values of screening efficiency and resistance in order to detect manufacturing faults.

3.8.5 *Marking*

Each conductive suit shall carry at least the following permanent information:

- name or trade mark of the manufacturer,
- type reference and size (in accordance with ISO standards),
- year of manufacture.

Each conductive item shall carry a blue triangle firmly attached, by sewing, adhesion or other suitable means. This triangle will be:
- dark blue 3 mm border on light blue background,
- side dimension shall be 50 mm or smaller if the conductive item is too small for such a triangle.

3.8.6 *Packaging*

As the conductive thread of the conductive fabric may become oxidized in the ambient air, the conductive fabric shall be packaged so that such oxidation is retarded during long storage. For example, the conductive suit may be packaged inside a plastic bag with tissue paper protecting the conductive suit from contact with the plastic bag.

SECTION THREE — TYPE TESTS

4. Knitted or woven fabric used for the suit, hood, socks and gloves, and basic shielding fabric used for face shield

4.1 *Flame retardancy test*

4.1.1 *Principle of test*

Ignition of a rectangular test specimen vertically hung, by a standard ignition specimen, according to prescribed conditions is the principle of the test, and includes the measurement of the burned area and classification of the tested fabric according to results.

4.1.2 *Test apparatus*

Apparatus shall consist of:

- a test chamber,
- a specimen holder,
- accessories.

4.1.2.1 The test chamber (see Appendix C, Figures C1, C2, C3 and C4, page 44) is made of approximating 1.5 mm thickness steel-plates. The interior walls of the chamber will be painted black.

The chamber is composed of:

a) a steel box 570 mm wide × 400 mm deep × 1000 mm high, with an air vent in the lower part of the back and of the front. These air vents shall have the following dimensions:

height = 116 mm, length = 440 mm;

b) a glass door above the front air vent;

c) a 300 mm × 300 mm steel deflector plate, above the top of the chamber which is penetrated by a 200 mm diameter hole;

d) the test chamber shall have a support for the test specimen holder (see Appendix C, Figures C5 and C6, page 45). The lower part of the test specimen holder shall be placed 110 mm above the base of the chamber.

4.1.2.2 The test specimen holder (see Appendix C, Figures C5, C6 and C7, page 45) is composed of:

a) a support (1) on which two 5 mm thick bars (2), spaced 150 mm apart, are fixed.

b) two holding bars (3), 5 mm thick held on the two bars (2) with clips.

The support (1) and the bars (2) and (3) shall be of metal.

The size of bars (2) and (3) (see Appendix C, Figure C6) shall be such that the test specimen is well supported.

4.1.2.3 The accessories include:

a) standard ignition linen specimen: whitened, not dressed, textile 67% polyester, 33% cotton — 110 g/m².

b) clamp;

c) clips;

d) scale (0.001 g precision);

e) pattern for test specimen cutting;

f) tracing-paper;

g) a mirror of approximately 250 × 300 mm, placed in a corner of the chamber, used to observe the burning on the rear of the fabric.

4.2 *Test specimens*

4.2.1 *Shape and dimensions*

Rectangular test specimens shall have dimensions of 150 mm × 300 mm after being attached to the specimen holder.

For knitted fabric (e.g. socks and gloves) the manufacturer shall provide flat test specimens with the above dimensions.

4.2.2 *Number*

a) Woven fabric

Tests shall be performed on three test specimens which are cut so that their length is parallel with the warp direction and three test specimens having their length parallel to the weft direction.

b) Knitted fabric

Only three test specimens shall be provided for knitted material unless it is not directionally uniform. In this case, six test specimens shall be provided (three for each direction).

4.2.3 *Sampling*

The outlines of the test specimens are drawn from the model so that their length corresponds to the direction of test.

The test specimens shall be cut so that:
- the middle point is on a 45° oblique line in regard of edges of a roll of fabric;
- the sides are parallel with the exterior edges of a roll of fabric.

A distribution of test specimens shall be taken in places where no defect appears. The outlines of the exterior of the test specimen shall be at least 50 mm from the edges of the roll of fabric.

4.3 *Procedure of test*

For each test specimen, the procedure of the test shall be as follows:

4.3.1 *Preparation of standard ignition specimen* (see Appendix C, Figure C8, page 45)

Cut a 25 mm × 80 mm strip of polyester-cotton (see Sub-clause 4.1.2.3) (the length is parallel with the warp direction). This textile strip is folded in the length direction to 25 mm × 20 mm dimensions. The ends of the specimen are put in the interior of the fold (Appendix C, Figure C8).

4.3.2 *Clamping standard ignition specimen*

The standard ignition specimen shall be clamped in the centre of the lower part of the test specimen. The clamp shall be fixed horizontally, so that:

- the standard ignition specimen has two thicknesses on each side of the test specimen,
- the end of the standard ignition specimen is 10 mm lower than the lower part of the test specimen.

4.4 *Test*

The test specimen is fixed on the specimen holder, so that the lower part of the test specimen coincides with the lower part of the specimen holder. The standard ignition specimen must be equidistant from the vertical rods.

The specimen holder is hung vertically in the test chamber.

A standard ignition specimen shall burn normally for about 25 s to 30 s.

Apply a flame to the lower part of the standard ignition specimen until it is ignited (about 2 s) and immediately close the door of the test chamber.

Observe the burning test specimen during test and note the following:

- points of residual afterglowing,
- melting,
- distortion of test specimen,
- smoke.

Measurement of burned area:

At the end of the test and after 15 min in the atmospheric conditions according to code 18 °C–28 °C/45%–75% of IEC Publication 212, using scissors, remove the completely burned or melted areas,

- lay the test specimen flat on the model so that remaining contours coincide with the model ones,
- measure the burned area of the test specimen by cutting up and scaling tracing-paper planimetry, or measurement of a geometric area.

4.5 *Results*

The test is considered as successful if the following conditions are met by each of the six specimens:

- the burned area of test specimen is less than or equal to 100 cm^2,
- the burned area does not extend to the vertical parts of the specimen holder, nor to the upper edge of the test specimen.

4.6 *Electrical resistance*

Either method A or method B below shall be used to determine the electrical resistance of the fabric. In case of dispute, method B shall be used.

Note. — Standard procedures to determine electrical resistance of fabric in connection with its antistatic properties are unreliable when the electrical resistance of highly conductive fabric has to be determined. Indeed, these standard procedures do not take into account the interference of the transition resistance from electrode to test specimen which is of primary importance when low resistance test specimens have to be measured.

4.6.1 *Method A*

4.6.1.1 *Apparatus*

a) Measuring electrodes

Electrical resistance measurements of textile materials in general require the use of a special electrode system for making electrical contact with the test specimen.

Such a measuring electrode system consists of a cylindrical centre-electrode (1) surrounded by a ring-electrode (2), respectively indicated as (1) and (2) in Figure C9, page 46.

The material of these electrodes shall be copper. Both electrode parts are mounted together with an insulating plastic disc (3) 10 mm thick. A well chosen number of screws (5) lock the electrodes to the plastic disc.

The height of the system (*h* of Figure C9) shall be such that the total weight of the system inclusive of the plastic disc, screws and electrical connecting parts is 20 ± 0.5 N. As a consequence, the contact pressure on the test specimen will correspond to approximately 4000 Pa. Special care shall be taken with those surface parts which will make contact with the test specimen (surfaces 6 in Figure C9). All surfaces 6 shall be:

- in one plane,
- lapped,
- gold plated. The thickness of the coating will be 5 ± 1 μm.

b) Resistance measurement

For the resistance measurement, a low resistance measuring device with a range of 0 to 1 Ω and an accuracy of 1 mΩ shall be used.

4.6.1.2 *Preparation of test specimens*

a) Number and dimensions of test specimens

Three pieces approximately 120 mm × 120 mm shall be cut from the fabric to be tested.

b) Contact coating on test specimen

In order to decrease the transition resistance between electrode-system and test specimen, the surfaces of the samples in contact with the electrodes (upper surface shown in Figure C9) shall be coated with a conductive paint having characteristics as described in Appendix A.

An oxidation process might deteriorate the conductivity of the paint on the test specimen. As a consequence, the measurements should take place within 24 h after the paint has been applied to the test specimen.

c) Conditioning of test specimen

Before applying the paint and carrying out tests, the test specimens shall be conditioned according to code 24 h/23 °C/50% of IEC Publication 212.

4.6.1.3 *Procedure*

The test specimen shall be laid on a flat insulating surface. The electrode set shall be placed on top of the test specimen to match exactly the coated pattern on the test specimen.

The ohmmeter as specified in item *b)* of Sub-clause 4.6.1.1 is connected to the electrode system and the measured value is recorded. Electrical resistance R_s is given by formula:

$$R_s = R_{\text{measured}} \times \frac{\text{width}}{\text{length}}$$

Numerical application (Method A):

$$R_s = R_{\text{measured}} \times \frac{(69.2 + 50.4) \times 3.14/2}{(69.2 - 50.4) / 2} = R_{\text{measured}} \times 20$$

4.6.1.4 *Evaluation*

The arithmetic mean value is calculated from three measured values. It shall be lower than 1 Ω.

4.6.2 *Method B*

4.6.2.1 *Apparatus*

The following apparatus is needed for the test:
- one alternating current generator of power frequency, allowing an adjustable and regulated load current of up to 2 A at 30 V;
- one a.c. ammeter;
- two contact electrodes, providing a contact surface of 20 mm × 20 mm on both faces of cloth test specimen. Contact pressure shall be more than 100 kPa (see Appendix C, Figure C10, page 47);
- two voltage measuring electrodes, such as sewing pins or needles;
- one a.c. voltmeter.

4.6.2.2 *Preparation of test specimens*

Four clothing test specimens measuring approximately 200 mm × 20 mm are respectively cut in warp, weft and two perpendicular directions making a 45° angle with warp and weft (see Appendix C, Figure C12, page 47).

These test specimens will be tested successively after a 24 h conditioning using the code 24 h/23 °C/50% of IEC Publication 212.

4.6.2.3 *Procedure*

The test specimen is placed unstretched between the contact electrodes (see Appendix C, Figure C10).

The voltage measuring electrodes are inserted at a distance of 100 mm apart (Figure C10).

The electrical circuit is completed (see Appendix C, Figure C11, page 47). A 0.2 A current is established through the unstretched test specimen.

After 1 min the voltage is measured.

4.6.2.4 *Test results*

The voltage measured is proportional to the electrical resistance of the test specimen.

The electrical resistance is given by the formula:

$$R_s = R_{\text{measured}} \times \frac{\text{width}}{\text{length}} = \frac{V \times l}{I \times L}$$

Numerical application (R_s in ohms and V in volts):

$$R_s = \frac{V}{0.2} \times \frac{20}{100} V$$

The arithmetic mean value of the four measured electrical values shall be lower than 1 Ω. No individual value shall be higher than 2 Ω.

4.7. *Current-carrying capability*

Either method A or method B below shall be used to prove the current carrying capability of the fabric.

In case of dispute, method B shall be used.

4.7.1. *Method A*

4.7.1.1. *Apparatus*

a) Measuring electrodes

The measuring electrodes consist of two copper blocks with a base of approximately 10 mm × 20 mm and a height of 20 mm.

b) Test specimen and electrode set-up

The electrode set-up is shown in Figure C13, page 48, of Appendix C. The test specimen as described in Sub-clause 4.7.1.2 is put in the middle of a polytetrafluorethylene plate with dimensions approximately 120 mm × 50 mm × 5 mm. Afterwards, the electrodes are placed on the painted part of the test specimen and loaded with a mass of 2 kg. If the load is electrically conductive, an insulation layer shall be provided between electrode and load.

c) Measuring equipment
- a variable power supply range 15 V d.c. – 2 A d.c.,
- a current measuring device range of 1 A – 2.5 A.

4.7.1.2 *Preparation of test specimens*

a) Number and dimensions of test specimens

Four test specimens shall be cut out of the fabric in warp, weft and two perpendicular directions making a 45° angle with warp and weft.

Dimensions approximately: 10 mm × 90 mm.

b) Contact coating on test specimen

In order to decrease the transition resistance between electrode system and test specimen, the test specimens shall be coated with a conductive paint having characteristics as described in Appendix A. The shaded surfaces of Figure C14, page 48, of Appendix C shall be coated with the conductive paint.

An oxidation process might deteriorate the conductivity of the paint. As a consequence, the measurements should take place within 24 h after the paint has been applied to the test specimen.

c) Conditioning of test specimens

Prior to applying the conductive coating and conducting the measurements, the test specimens shall be conditioned in normal room conditions using the code 24 h/23 °C/50% of IEC Publication 212.

4.7.1.3 *Procedure*

A variable d.c. source shall be applied so that a current of 0.5 ± 0.01 A flows through the electrode system, as described in Item *a)* of Sub-clause 4.7.1.1.

A period of 5 min will be allowed for stabilization of the temperature. During this period, it might be necessary to adjust the setting of the d.c. source so as to maintain the current at the 0.5 A level.

4.7.1.4 *Acceptance conditions*

After the 5 min period, the test shall be considered as successful if:

- the d.c. voltage of the source is lower than 1.5 V*,
- the test specimen does not show any deterioration or burned spots.

4.7.2 *Method B*

4.7.2.1 *Apparatus*

Same test-set as in Sub-clause 4.6.2.1, electrical resistance.

4.7.2.2 *Preparation of test specimens*

Same procedure as in Sub-clause 4.6.2.2.

4.7.2.3 *Procedure*

As in Sub-clause 4.6.2.3 except:

- a 1 A current is established through the test specimen,
- after 15 min, the voltage is measured.

4.7.2.4 *Test results*

During the test, there shall be no flame, incandescent point, smoke, or carbonization between the voltage measuring electrodes. The arithmetic mean value of four measured voltage values after 15 min shall be lower than 5 V*. No individual value shall be greater than 10 V.

4.8 *Cleaning requirements*

To ensure that the screening efficiency and flame retardant properties of the clothing do not deteriorate excessively after repeated cleaning, one or both of the following procedures shall be carried out. If the garment is not suitable for cleaning by one of the two methods, the manufacturer shall mark the garment accordingly, and only one of the two test methods need be used.

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* The values correspond to a maximum power per unit surface of 2500 W/m^2 that induces a maximum temperature rise of 50°C (relation between power per unit surface and temperature elevation is linear and does not depend on fabric).

4.8.1 *Laundering*

Two specimens of the garment shall be washed in an automatic, domestic washing machine, excess water removed and dried in a tumble drier. The apparatus and reagents shall have the following specifications:

a) Automatic washing machine capable of being operated under the following conditions: either
- a top loading, agitator type with a "normal" agitator speed of 70 ± 5 rev/min, or
- a front loading machine with a speed of 52 rev/min, revolving alternatively in each direction for 12 s, and 3 s rest in between,
- washing time adjustment controllable between 0 and 15 ± 1 min,
- spin speed: normal 515 ± 5 rev/min.

b) Drier of the rotary tumble type having a cylindrical basket approximately 750 mm in diameter and not less than 400 mm in depth, rotating at approximately 50 ± 5 rev/min, equipped with means for maintaining a drying temperature of 50 °C to 70 °C measured in the exhaust vent as close as possible to the drying cylinder, and providing a cooling period of 5 min when tumbling, at the end of the drying cycle.

c) Commercial detergent not containing bleach. The standard detergent specified in Table II of Amendment No. 1 to IEC Publication 456 for a detergent without perborate (type II), can be used in cases of dispute.

d) Dummy load: Pieces of undyed spun polypropylene fabric, mass approximately 0.16 kg/m^2.

- Place the specimens in the washing machine and add sufficient dummy load to make a total dry fabric load of 2 kg. Fill the machine to operate with 40 ± 4 litres of water and set the machine to operate at the normal setting (50 °C to 70 °C). If the mass of the test specimen(s) exceeds 2 kg, the amount of water shall be increased proportionately.

- Add sufficient detergent to provide good running suds and set the machine to wash for 10 min. (If necessary, advance the operation of the machine manually to begin the rinse cycle after 10 min of washing.) Continue until the end of the final spin cycle.

On completion of the final spin cycle, remove the specimens from the machine and place them and the dummy load (if any) in the tumble drier with the temperature of the exhaust from the drum set at 65 °C to 70°C (for normal fabrics). Operate the drier until the load is dry and continue tumbling, with the heat turned off, for 5 min. Remove the test specimens immediately. One wash-dry cycle will then have been completed.

4.8.2 *Dry cleaning*

Two test specimens of the garment material shall be dry cleaned using the following apparatus and reagents:

The apparatus shall consist of a cylinder, preferably of metal approximately 330 mm high and 220 mm in diameter (capacity approximately 11 l). The cylinder shall be mounted on an axis inclined at an angle of 50° to the axis of the cylinder when the latter is in a vertical position. The cylinder is filled approximately one-third full with 100% perchlorethylene, dry and free from acid, and rotated about its axis at a speed of 45 rev/min to 50 rev/min.

The test specimens are then taken from the cylinder and excess solvent removed from them by convenient means, such as centrifuging or squeezing between layers of white cotton cloth or white blotting paper. They are then laid on a muslin-covered frame or a non-rusting, metal screen. Heavy wrinkles are smoothed out with the hand and the test specimens are allowed to dry at room temperature.

One dry cleaning cycle will then have been completed.

4.8.3 *Acceptability of fabric*

When 10 wash-dry cycles, or 10 dry cleaning cycles, have been completed, the test specimens shall be placed on a flat surface and conditioned to the atmosphere for at least 4 h and then the screening efficiency and flame retardancy tests repeated. If the values measured in these tests no longer meet the specified requirements, the fabric shall be rejected.

4.9 *Screening efficiency*

Note. — Tests carried out in the actual conditions of this specification have shown that screening efficiency does not depend on test frequency between 50 Hz and 5 kHz. To facilitate testing, 5 kHz is chosen. At this frequency, the test is at least as severe as at 50 Hz or 60 Hz.

4.9.1 *Apparatus*

a) One 400 V r.m.s. sine wave voltage generator at 5 kHz.

b) One insulating circular plate 300 mm diameter.

c) One metallic circular plate 300 mm diameter with connection clip.

d) One insulating circular plate 400 mm diameter made from an elastomeric 3.5 ± 0.5 mm thick sheet having a surface hardness between 60° and 65° on Shore scale.

e) One electrode assembly weighing 3 kg built according to the scheme given in Figure C15, page 49, of Appendix C and fitted with a 100 kΩ shunt.

f) One measuring device (multimeter or oscilloscope) with constant input impedance greater or equal to 1 MΩ, in parallel with a capacitance of 47 pF maximum.

g) One voltmeter allowing measurement of 400 V r.m.s. at 5 kHz.

4.9.2 *Test mounting*

4.9.2.1

The following parts are assembled in the specified order upon a grounded horizontal support (Appendix C, Figure C16, page 49):
- circular insulating plate 300 mm diameter,
- circular metal plate 300 mm diameter and 3 mm to 5 mm thick,
- circular elastomeric plate 400 mm diameter and 3 mm to 5 mm thick,
- test specimen, minimal dimensions 120 mm × 120 mm,
- electrode assembly (not allowed to pass beyond the edge of test specimen). The thickness of the polyvinyl insulating plate between the electrode and the test specimen shall be 0.8 mm (Figure C15).

4.9.2.2 *Earth connection*

The following parts are connected together and earthed:
- frame connection of voltage generator,
- earth connection of electrode assembly,
- frame connection of voltmeter.

4.9.2.3 *Line connection*

The following parts are connected together and insulated from earth:

- line connection of voltage generator,
- connection clip of metallic plate 300 mm diameter,
- line connection of voltmeter.

4.10 *Test procedure*

4.10.1 Determination of reference voltage

Without the fabric specimen, a voltage of 400 V r.m.s. at 5 kHz is applied between the line and earth connections. The voltage is read on the measuring device and noted as U ref.

4.10.2 *Measuring with test specimen*

The fabric test specimen is installed (Sub-clause 4.9.2.1) and the test procedure is carried out in the same way as described in Sub-clause 4.10.1. The measured voltage U is recorded.

4.10.3 *Screen efficiency*

Screen efficiency is given by formula:

$$SE_{\mathrm{dB}} = 20 \log_{10} \left(\frac{U \text{ ref}}{U} \right)$$

4.11 *Acceptance criteria*

The screening efficiency shall be greater than 40 dB.

5. **Conductive clothing** (complete assembly)

5.1 *Conductive gloves*

Two electrodes shall be painted on the glove using a conductive paint having the characteristics described in Appendix A. One shall be 5 mm square, on the end of the longest finger, the other shall be 25 mm long, parallel and adjacent to the open edge of the glove and about 5 mm wide (see Appendix C, Figure C17, page 50). The resistance measured between these electrodes shall not exceed 100 Ω.

To provide protection from spark discharges directly to the hand through the material, the closest spacing between individual adjacent conducting components in the material shall not exceed 5 mm even when the material is stretched with a force of up to 50 N in any direction.

5.2 *Conductive socks*

An electrode 25 mm long and parallel to the open edge of the sock and about 5 mm wide shall be painted on the specimen using a conductive paint having the characteristics described in Appendix A. The sole of the sock shall then be placed on a metal plate and 4 mm diameter nickel stainless steel balls, conforming to ISO Standard 3290, poured into the sock to a depth of 20 mm (see Appendix C, Figure C18, page 50). The resistance shall then be measured between the electrode and the metal plate and shall not exceed 100 Ω.

5.3 *Conductive footwear*

The footwear shall be placed on a metal plate and one electrode placed on the inside of the sole below the ankle opening. Nickel stainless steel balls, 4 mm in diameter, conforming to ISO 3290-1975, shall then be poured in around the electrode to cover the complete sole to a depth of 20 mm at the heel (see Appendix C, Figure C19a, page 51).

The resistance shall then be measured between the metal plate and the electrode and shall not exceed 500 Ω.

If straps are used to connect the footwear electrically to the suit, then the resistance shall be measured between the strap and the metal plate on which the footwear is resting, with the steel balls inside but not connected in the circuit (see Appendix C, Figure C19b, page 51).

Any metal parts in the footwear larger than 10 cm^2 must be electrically bonded together during manufacture.

If conductive socks are used in conjunction with high-resistance shoes, the resistance of these shoes shall not exceed 0.5 MΩ. The footwear can be used alone, without a complete conductive suit, for protection against annoying spark discharges when working in an electric field.

5.4 *Hood and face shield*

Equipment used for shielding the head and face shall meet the requirements of Sub-clauses 5.6.3 and 5.6.4 and allow for free movement of the head.

5.5 *Conductive suit without fittings*

Fittings are those described in Sub-clauses 5.1 to 5.4.

5.5.1 *General*

The electrical resistance shall be measured between the points indicated, which shall be at least 50 mm from the edge of the material or joint location:

a) In the case of a two-piece suit, three points shall be chosen, and shall be at least 50 mm from the edge of the joint.

b) Measurements shall be made with the suit, or suit pieces, mounted on (supported by) a manikin or non-conductive model (dummy) to support the suit, to conform to the shape it will assume when worn by the worker.

c) Contact electrodes of 25 mm square aluminium foil pads, secured to the suit with electrical tape (to ensure sufficient contact pressure), shall be used. When this pressure cannot be achieved due to the location on "body" shape, sufficient pressure shall be achieved by applying pressure with the hand to obtain this lowest reading. A safety belt shall be secured around the waist to obtain a good contact between the upper and lower portions of a two-piece suit.

5.5.2 *Measurement locations*

a) In the case of a two-piece suit, three points shall be chosen, and shall be at least 50 mm from the edge of the joint.

b) For all suits, measurements shall be made between each point indicated, with contact points being approximately 50 mm from the edge of the cuff, leg, and bonding strap ends, and neck and crotch seams.

c) Points to be measured:
  - end of each arm,
  - end of each leg,
  - end each arm to end each leg,
  - neck and crotch of the complete suit,
  - bonding lead and end of each arm,
  - bonding lead and end of each leg,
  - bonding lead between the hood and the facial conductive shield.

5.5.3 *Acceptable values*

The suit shall be considered acceptable if the resistance values measured between any points, including the bonding lead, do not exceed 40 Ω.

Note. — Readings may be made using electrodes other than those specified in Item *c)* of Sub-clause 5.5.1, provided the readings obtained are less than those required. The resistance of alligator clips or similar attachment devices should be included in the above readings.
In case of dispute, the measurements using the standard electrodes specified should apply.

5.6 *Complete clothing*

5.6.1 *General*

Care shall be taken if the complete clothing is made up of more than one piece (e.g. separate jacket or trousers) to ensure that the method of attachment of the individual pieces can be made electrically sound and that they cover the body of the worker completely.

5.6.2 *Visual checking*

A visual inspection shall be made of the complete clothing to ensure that it is the correct size stated and that all component parts fit together. Zip fasteners, metal press studs and metal hooks and eyes shall be checked to ensure that they are correctly inserted and that nothing prevents them from making good electrical contact. The stitching shall be examined to ensure that it is continuous and that the two or more pieces being joined are in good electrical contact.

The visual inspection shall ensure that the agreed blue triangle denoting conductive clothing is prominently affixed on each conductive item of the complete suit.

5.6.3 *Electrical resistance*

All components of the clothing intended for use together shall be assembled according to the manufacturer's instructions and the electrical resistance measured between the following points:

a) In the case of two or more piece suits, three or more points shall be chosen, in accordance with Sub-clause 5.5, and shall be 50 mm from the edge of each joint, as noted in the relevant sub-clause.

b) In addition to the measurements required in Sub-clause 5.5, measurements shall be made, using the procedures specified in Clause 5, as applicable:
  - palm of each hand,
  - sole of each foot,
  - palm of each hand and sole of each foot,
  - bonding lead and each palm,
  - bonding lead and each foot,
  - hood, face shield, shielding hat and neck of suit (see Appendix D).

The resistance between any of the above parts shall not exceed 60 Ω.

Note. — The note at the end of Sub-clause 5.5.3 should apply also to this sub-clause.

5.6.4 *Screening effect*

This test shall be carried out under the maximum phase/earth voltage for which the clothing is used. The ground shall be at least at a distance D given by formula:

$$D = \frac{U \text{ test}}{100} + 0.5 \text{ (with } D \text{ in m and } U \text{ in kV)}$$

The manikin shall be equipped with:
- a conductive belt placed against the skin,
- an insulating suit,
- the complete conductive suit under test (which includes the face shield or any other means to protect the face). (See Appendix E.)

Good insulation between the conductive suit and the conductive belt worn by the manikin shall be checked before and after the test.

Direct reading is made on the shielded ammeter of:
- the total current I_1, flowing between the live electrode and the conductive suit connected to its conductive belt.
- the current I_2 flowing between the live electrode and the conductive belt.

The ratio $\frac{I_1}{I_2}$ shall be such that the efficiency coefficient $\frac{I_1}{I_1 + I_2}$ shall be not less than 99%.

Note. — 99% corresponds to 40 dB (see ISO Standard 479).

SECTION FOUR — SPECIAL CLAUSES

6. Sampling tests

After agreement between the manufacturer and the purchaser, all the type tests described above or only part of them, may be carried out again as sampling tests. They shall be made under the responsibility of the manufacturer who shall make their results available to the purchaser. The sampling plan and the acceptable quality level shall be as in the following table:

TABLE I

Lot or batch size	Sample size	Acceptance number	Rejection number
2 to 15	2	0	1
16 to 25	3	0	1
26 to 90	5	0	1
91 to 150	8	0	1
151 to 500	13	1	2
501 to 1 200	20	1	2
1 201 to 10 000	32	2	3

7. Routine tests

7.1 If the different parts of the conductive suit are provided by one supplier, he shall check on each conductive suit:

a) quality,

b) compatibility,

c) electrical continuity.

7.2 If the user buys the different parts of the suit from different suppliers each supplier shall check on each product:

a) general fashion,

b) electrical resistance.

Recommendation: The purchaser should verify the compatibility and the electrical continuity of the different parts of the complete suit.

TABLE II

Part of suit	Conductive gloves	Conductive socks	Conductive footwear	Hood and face shielding	Conductive suit without fittings	Complete clothing
Sub-clause	5.1	5.2	5.3	5.4	5.5	5.6

8. Acceptance checks and tests

An acceptance test is a contractual test to prove to the purchaser that the device meets certain conditions of its specification (see IEC Publication 50 (151), reference number IEV 151-04-20). These tests may be carried out on every unit (routine tests) or on a sample unit (sampling test).

If a purchaser indicates in his specification that the device shall meet this IEC specification only, the acceptance tests are those (both routine and sampling) which are specified in this document.

The purchaser may however, if he wishes, ask for additional tests or modify the sampling size but shall include this in his specification.

The purchaser may wish to witness the tests, have someone witness them or simply accept the results of the tests as carried out by the manufacturer. He may also specify that the tests be carried out in an independent laboratory of his choosing or even in his own laboratory.

Further, the purchaser may specify the additional tests or larger sampling sizes when he is purchasing from a new manufacturer, because he has experienced problems with a particular manufacturer, or because he is purchasing a new product or a new design.

9. Modification

Before carrying out any modification of any characteristic, whether specified herein or not, the manufacturer shall obtain the agreement of the purchaser.

Any modification of conductive suits may require new type tests, in whole or in part (if the degree of modification so justifies) as well as a change of the type reference.

APPENDIX A

DETERMINATION OF ELECTRICAL RESISTANCE PROPERTIES OF FABRIC INTENDED FOR CONDUCTIVE CLOTHING FOR LIVE WORKING. EVALUATION OF CONDUCTIVE PAINT

The conductive paint applied to the test specimen surface is essential for the measurement of the correct value for the surface resistance.

The test procedure as described in this appendix allows for an evaluation of the degree of conductivity of a conductive paint.

A1. **Procedure**

- A glass plate should be coated with two layers of the paint under test. Allow for a drying period between the two layers. The maximum value of the thickness of total coating should be close to 50 µm. The surface coated should be at least 200 mm × 200 mm.
- The surface resistivity of the coating will be determined according to the test procedure described in Sub-clause 4.6. More details on this test procedure are given in this appendix.

A2. **Appreciation**

- The arithmetic mean value of the three measured surface resistance values should be less than 1 Ω.
- No individual value should be greater than 2 Ω.
- The so-called "silver paint" used as surface paint for esthetic reasons or protection against corrosion is in reality aluminium paint and is not suitable as conductive paint.

A3. **Remarks**

- As conductive paint, colloidal silver paint is recommended.
- Silver paint is available commercially with a high conductivity, either air-drying or low-temperature baking varieties.
- Before a conductive paint is used as an electrode material, it should be established that the solvent in the paint does not attack the material so as to change its electrical properties.

EXAMPLE OF APPLICATION OF THE CONDUCTIVE COATING

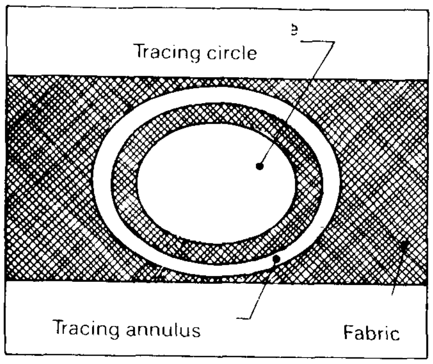


FIG. A1. – Area to be painted, covered with circle and annulus for tracing.

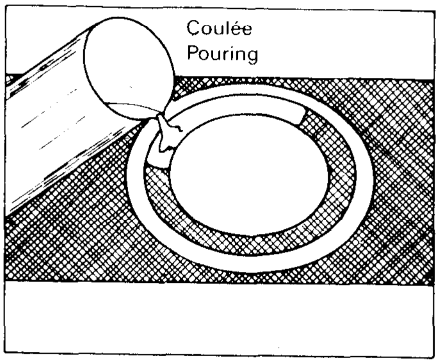


FIG. A2. – Pouring of liquid paraffin between tracing circle and annulus.

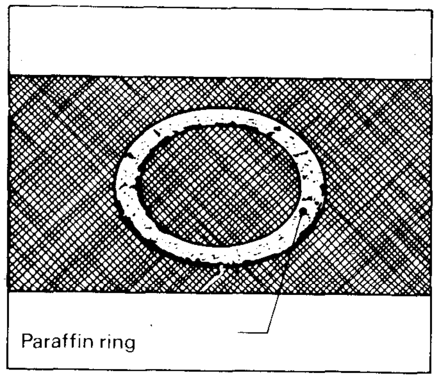


FIG. A3. – Solidified paraffin ring after removal of the tracing circle and annulus.

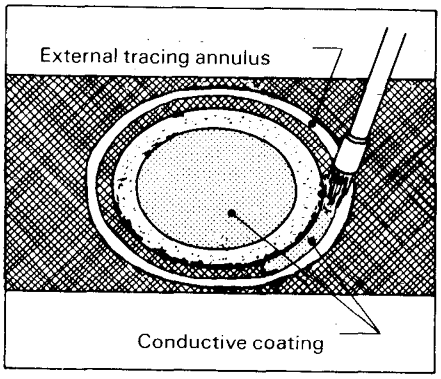


FIG. A4. – Application of the conductive coating.

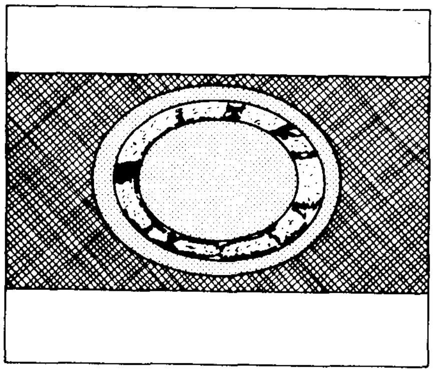


FIG. A5. – The paraffin ring can be peeled off when the paint has dried.

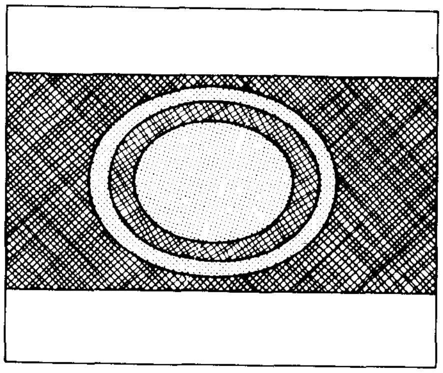
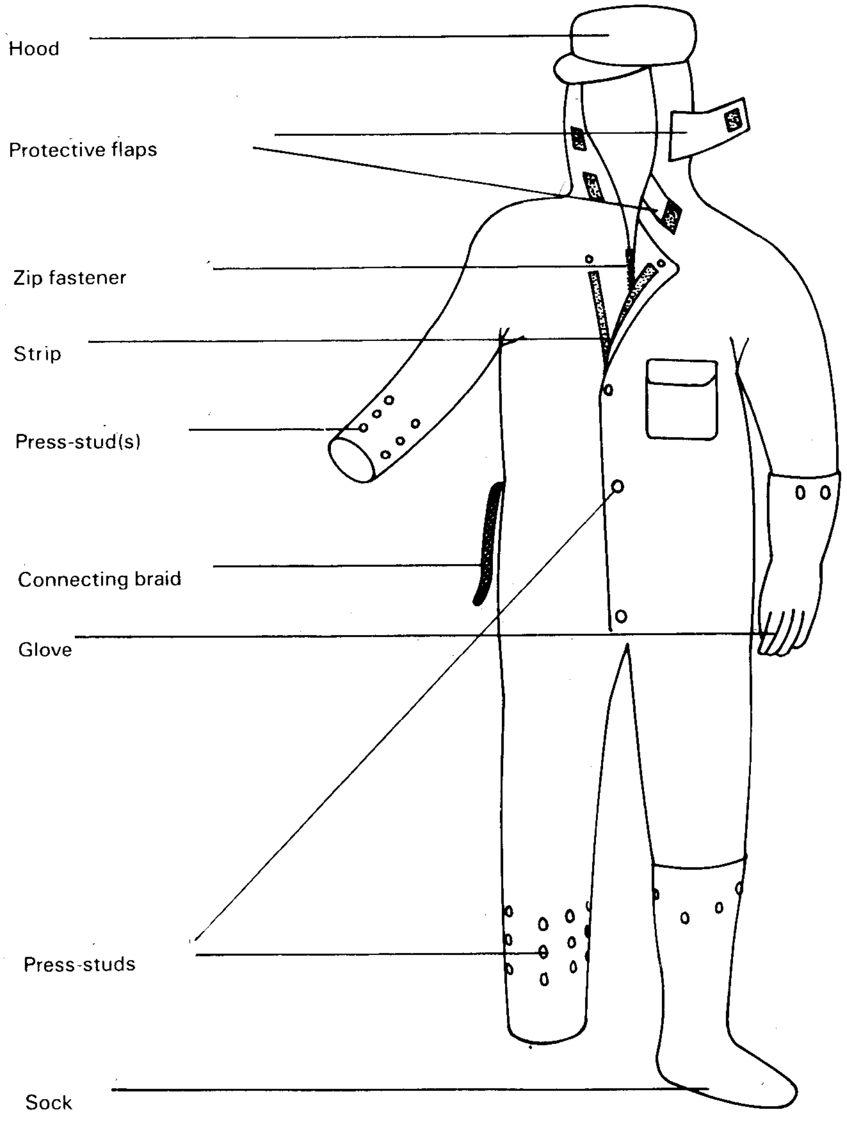


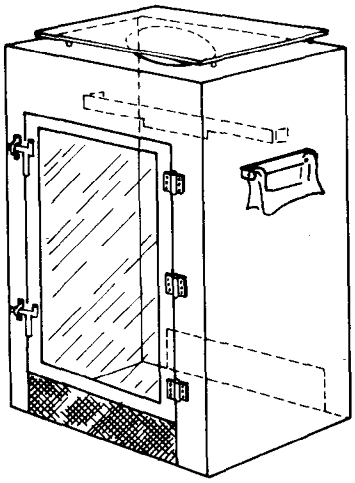
FIG. A6. – Test piece ready for the measurement.

APPENDIX B

EXAMPLE OF GENERAL ARRANGEMENT OF SUIT



APPENDIX C



Test chamber

FIGURE C1

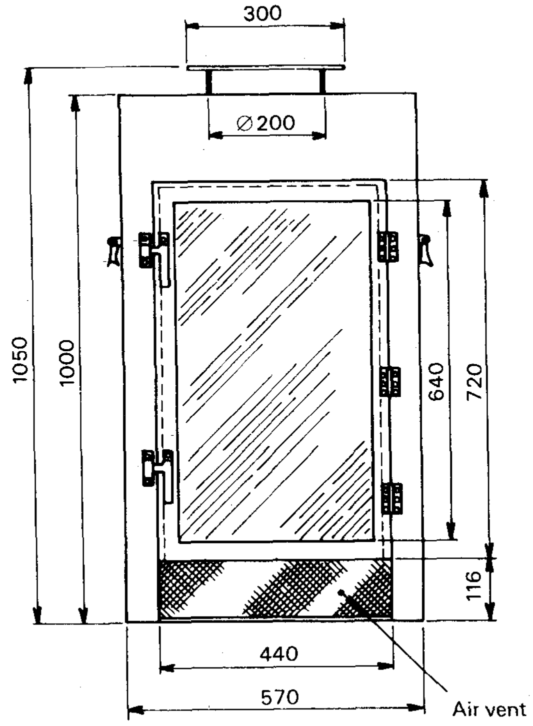


FIGURE C3

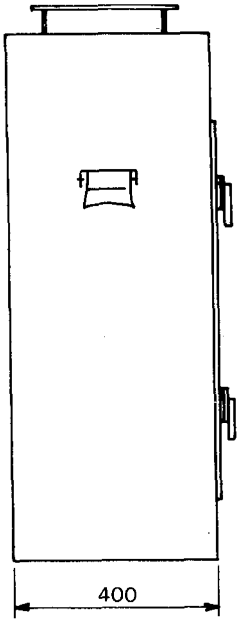


FIGURE C2

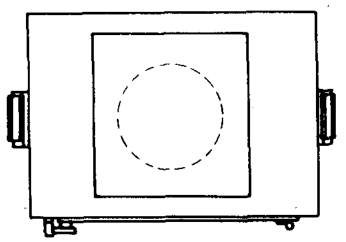


FIGURE C4

Dimensions in millimetres

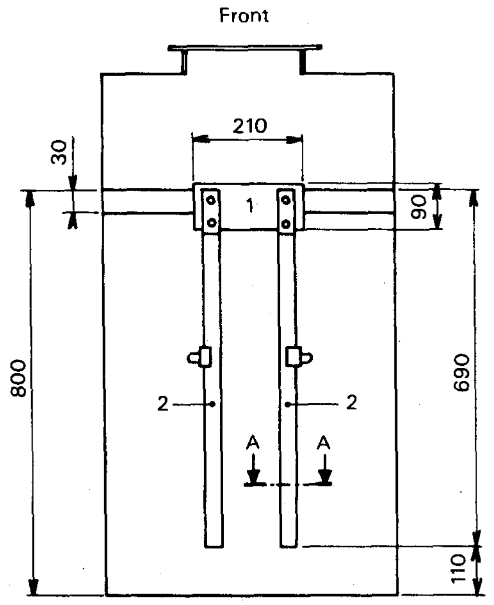


FIGURE C5

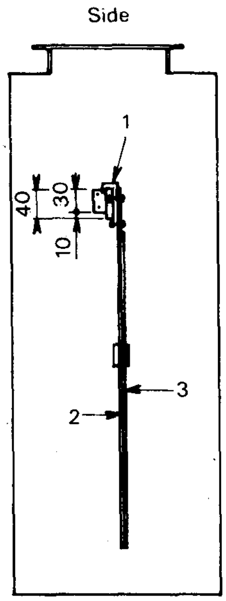


FIGURE C6

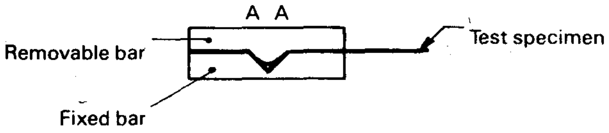
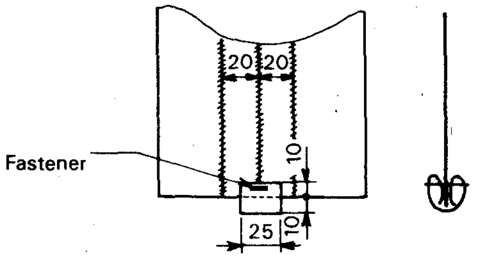
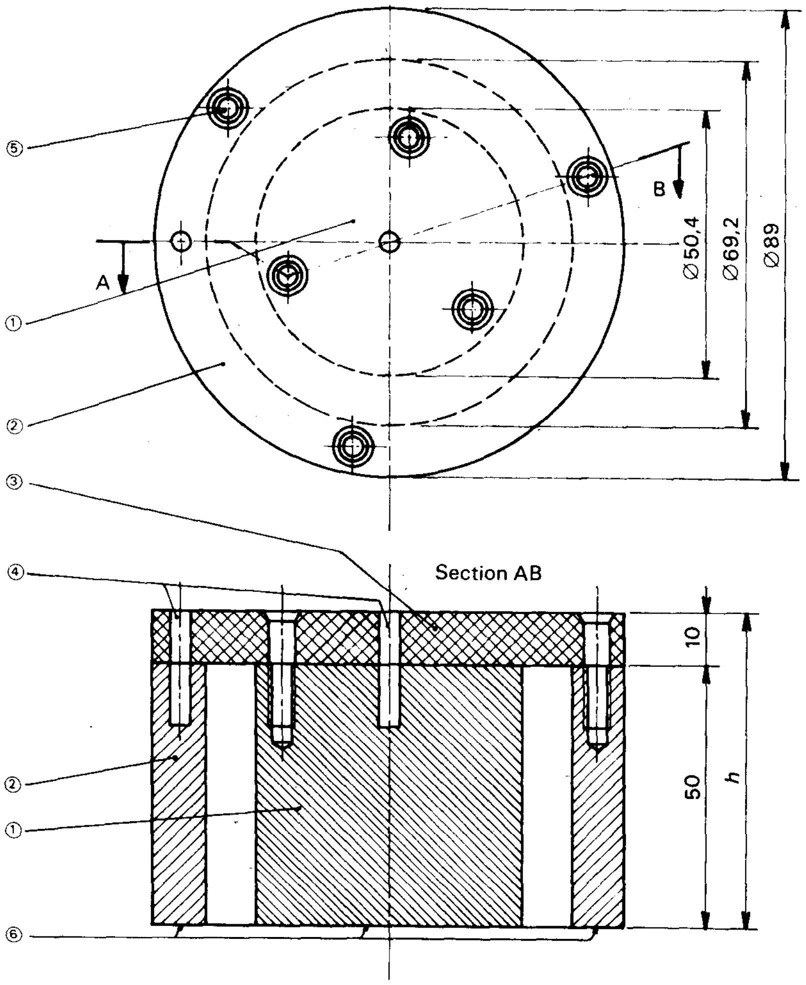


FIGURE C7



Dimensions in millimetres

FIGURE C8



① Outer electrode

② Inner electrode

③ Insulating plastic disc

④ Appropriate holes to accept connecting pins with wiring

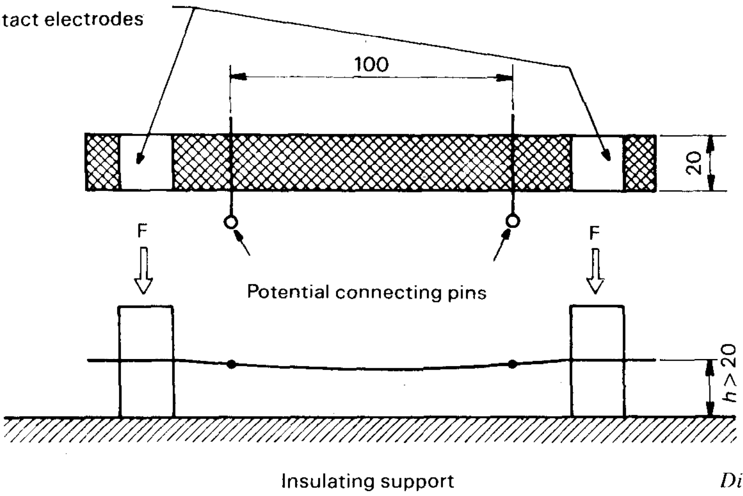
⑤ Mounting screws

⑥ Surfaces of electrode system in contact with test specimen

Dimensions in millimetres

Note. – Dimension *h* is chosen so that the total weight of the electrode system is 20 N.

FIG. C9. – Concentric electrodes for measurement of electrical resistance.



Dimensions in millimetres

FIG. C10. – Electrical resistance

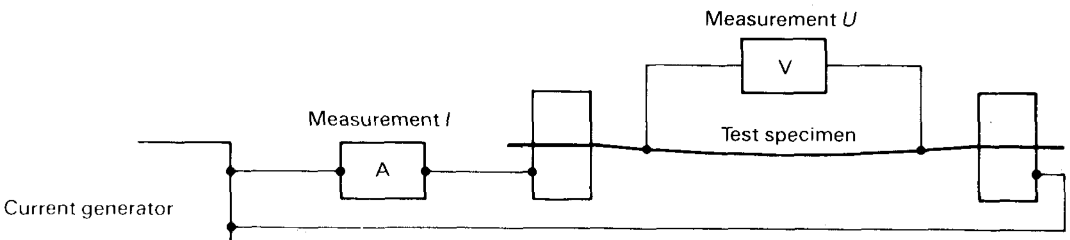
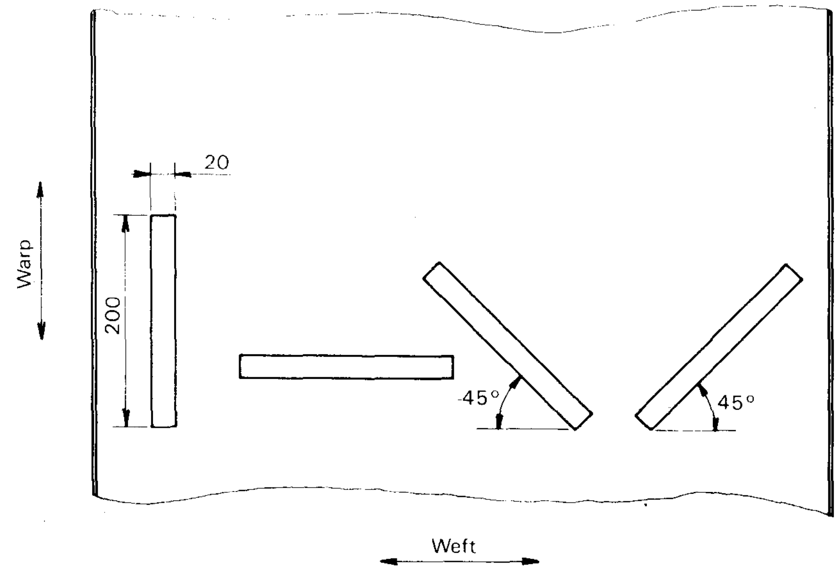


FIGURE C11



Dimensions in millimetres

FIG. C12. – Orientation of test specimens for electrical resistance and current carrying capability tests.

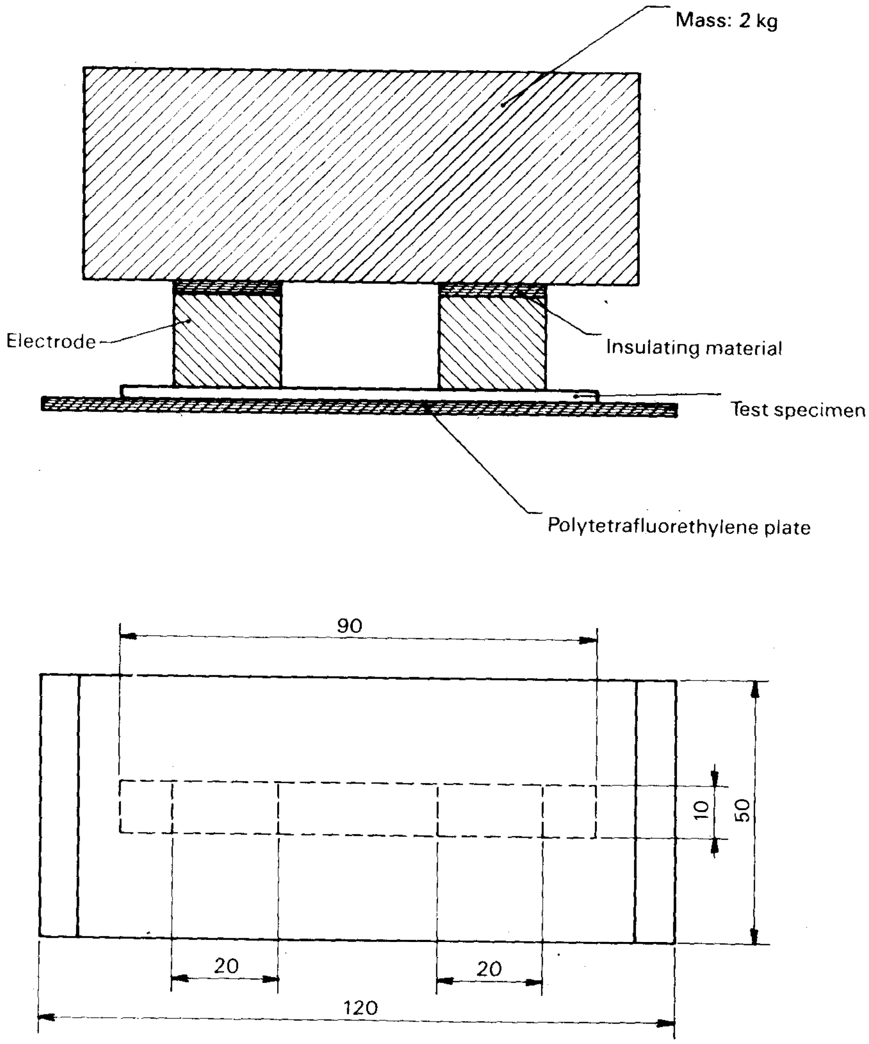
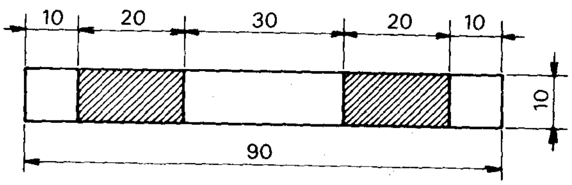


FIG. C13. – Electrode set up.



Note. – Shaded surfaces are coated with colloidal silver paint.

Dimensions in millimetres

FIG. C14. – Test specimen dimensions.

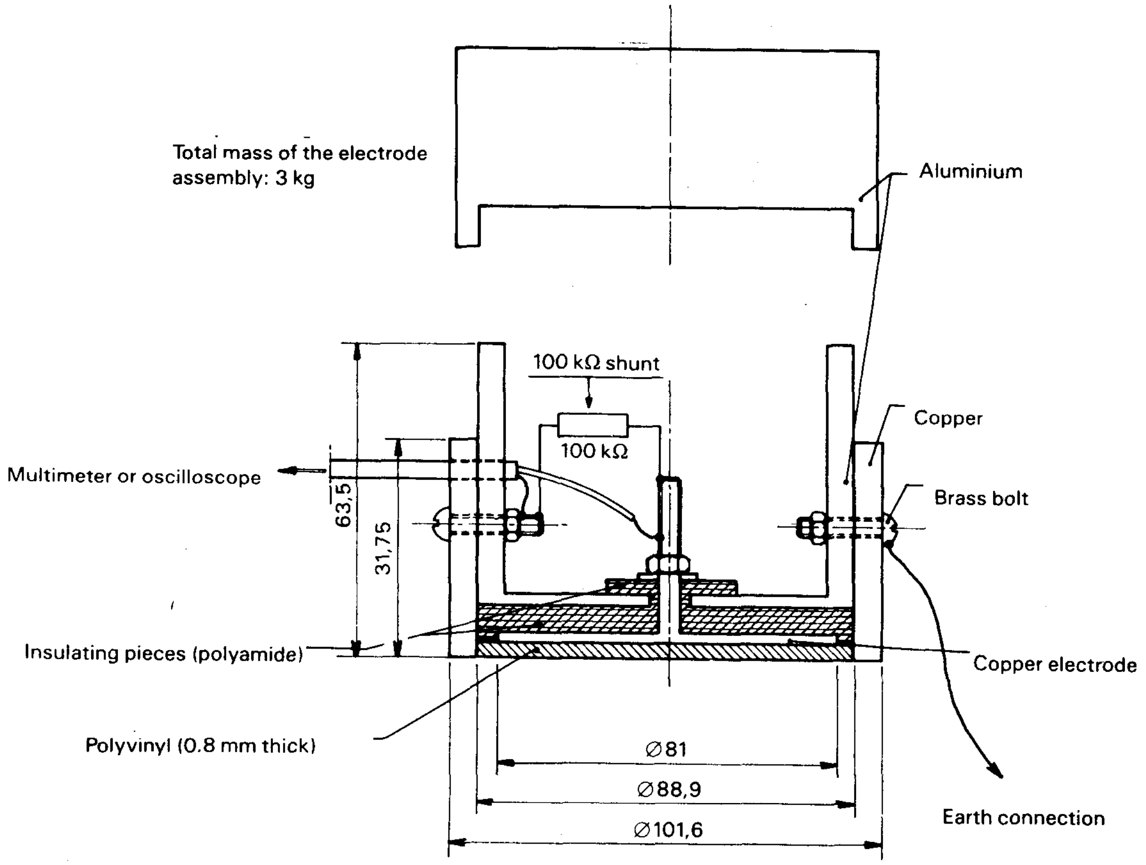
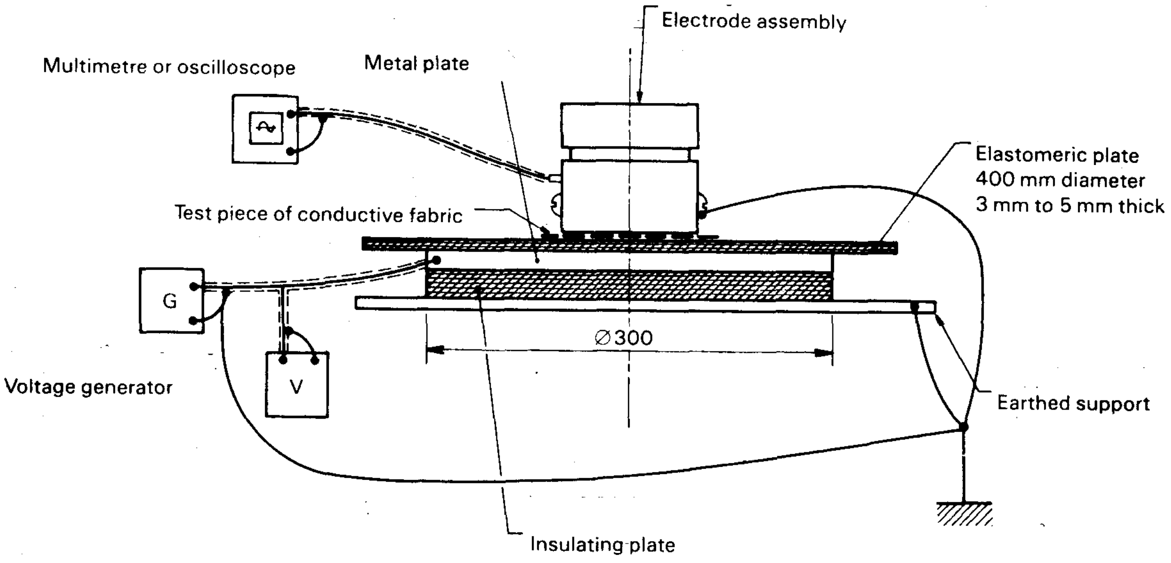


FIG. C15. – Screening efficiency : electrode assembly.



Dimensions in millimetres

FIG. C16. – Measure of the screening efficiency.

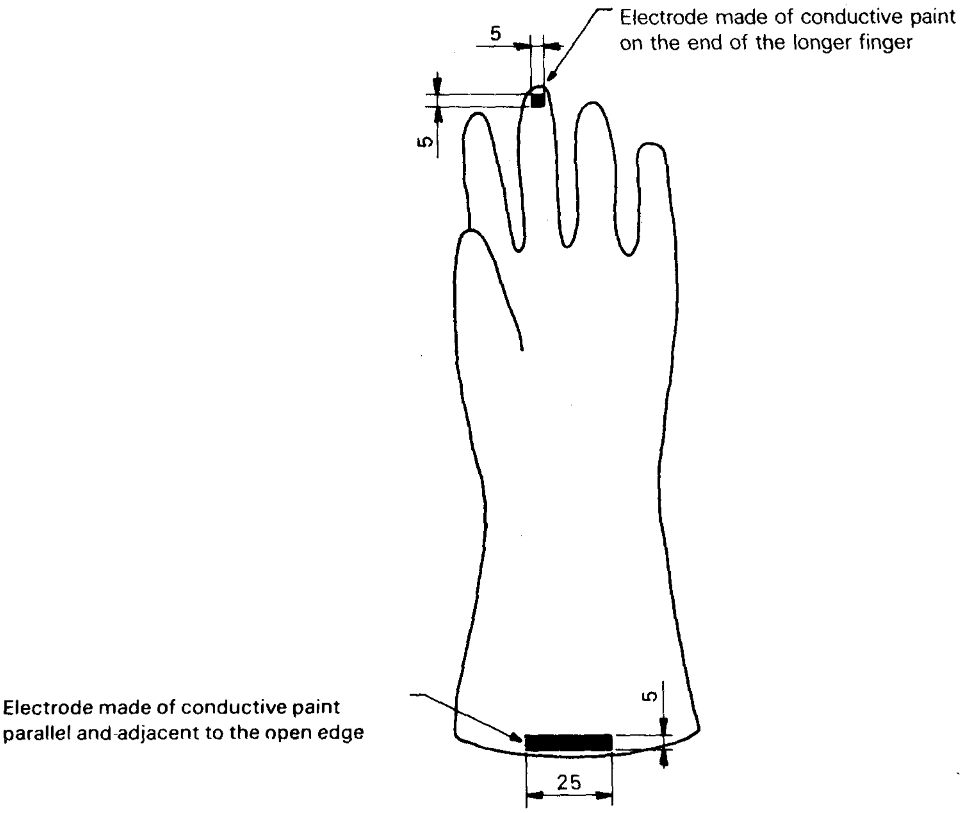
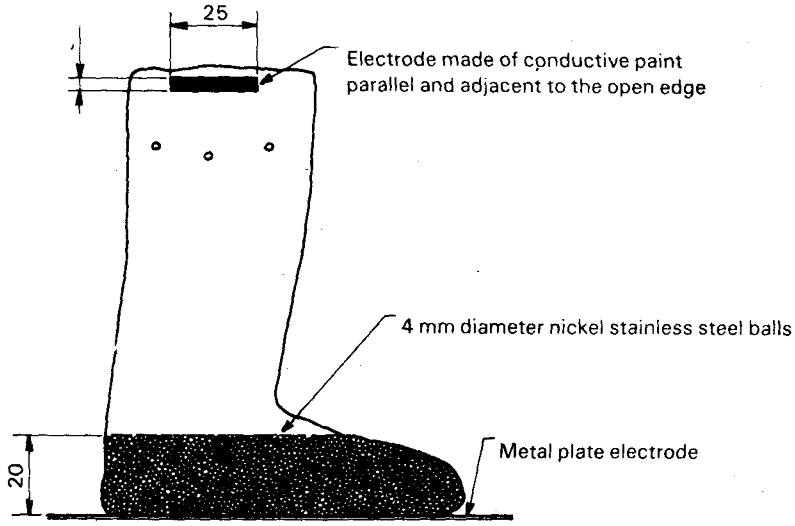

5
Electrode made of conductive paint
on the end of the longer finger
5
Electrode made of conductive paint
parallel and adjacent to the open edge
5
25

FIGURE C17


25
Electrode made of conductive paint
parallel and adjacent to the open edge
4 mm diameter nickel stainless steel balls
Metal plate electrode
20

Dimensions in millimetres

FIGURE C18

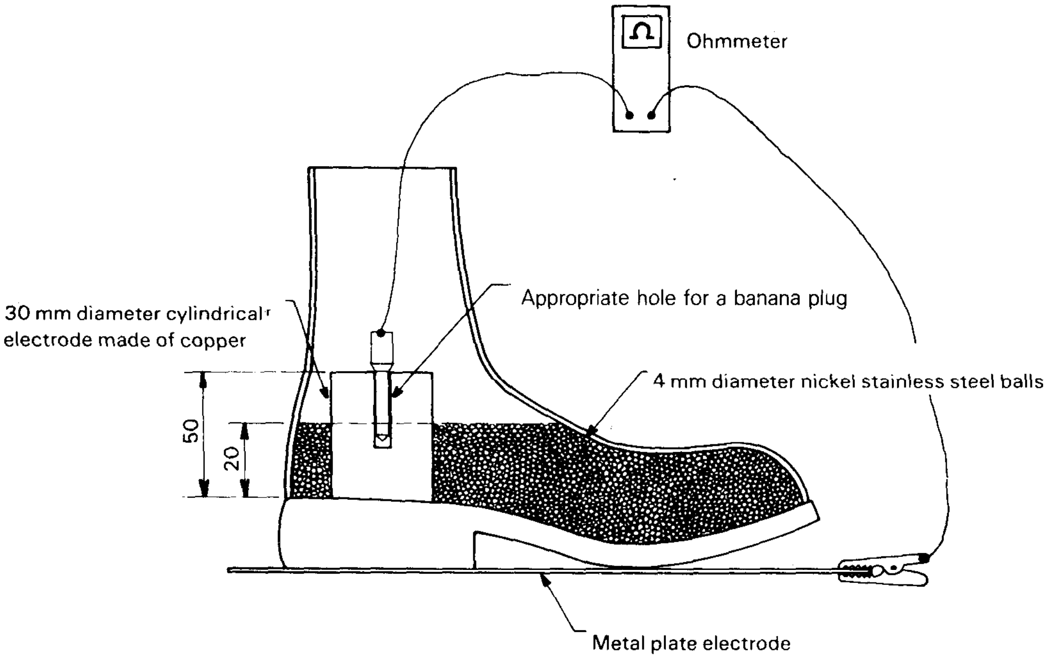

Ohmmeter
Appropriate hole for a banana plug
30 mm diameter cylindrical electrode made of copper
4 mm diameter nickel stainless steel balls
50
20
Metal plate electrode

FIGURE C19a

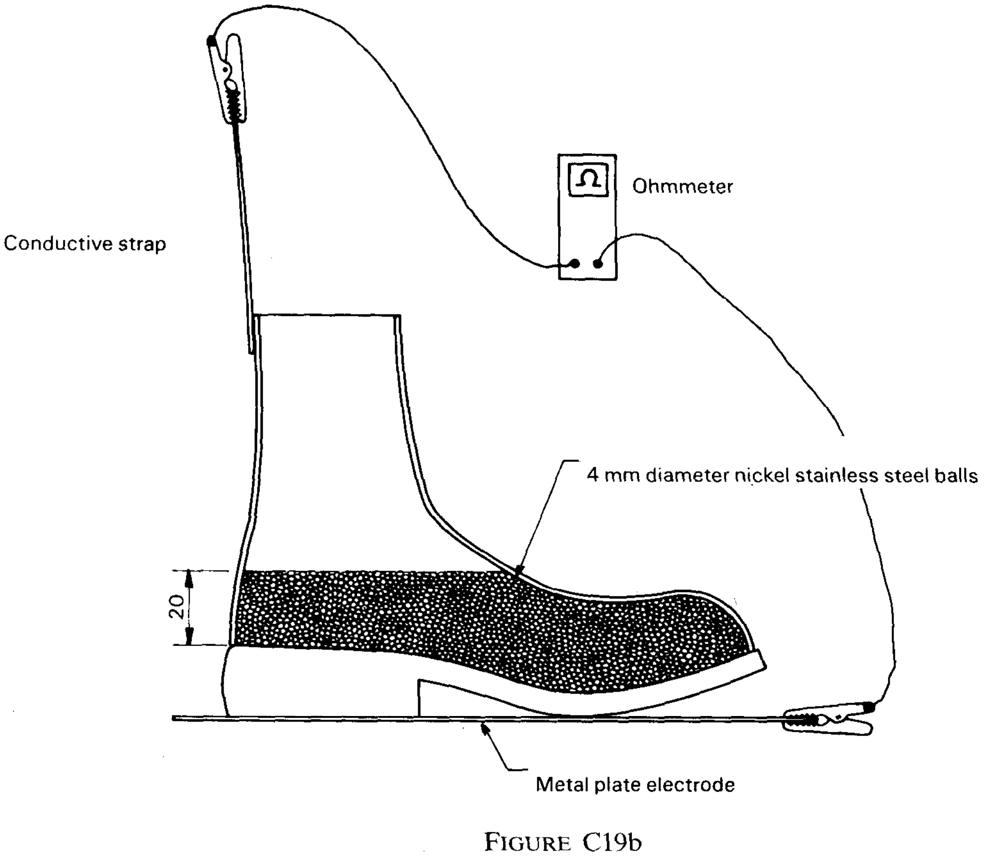
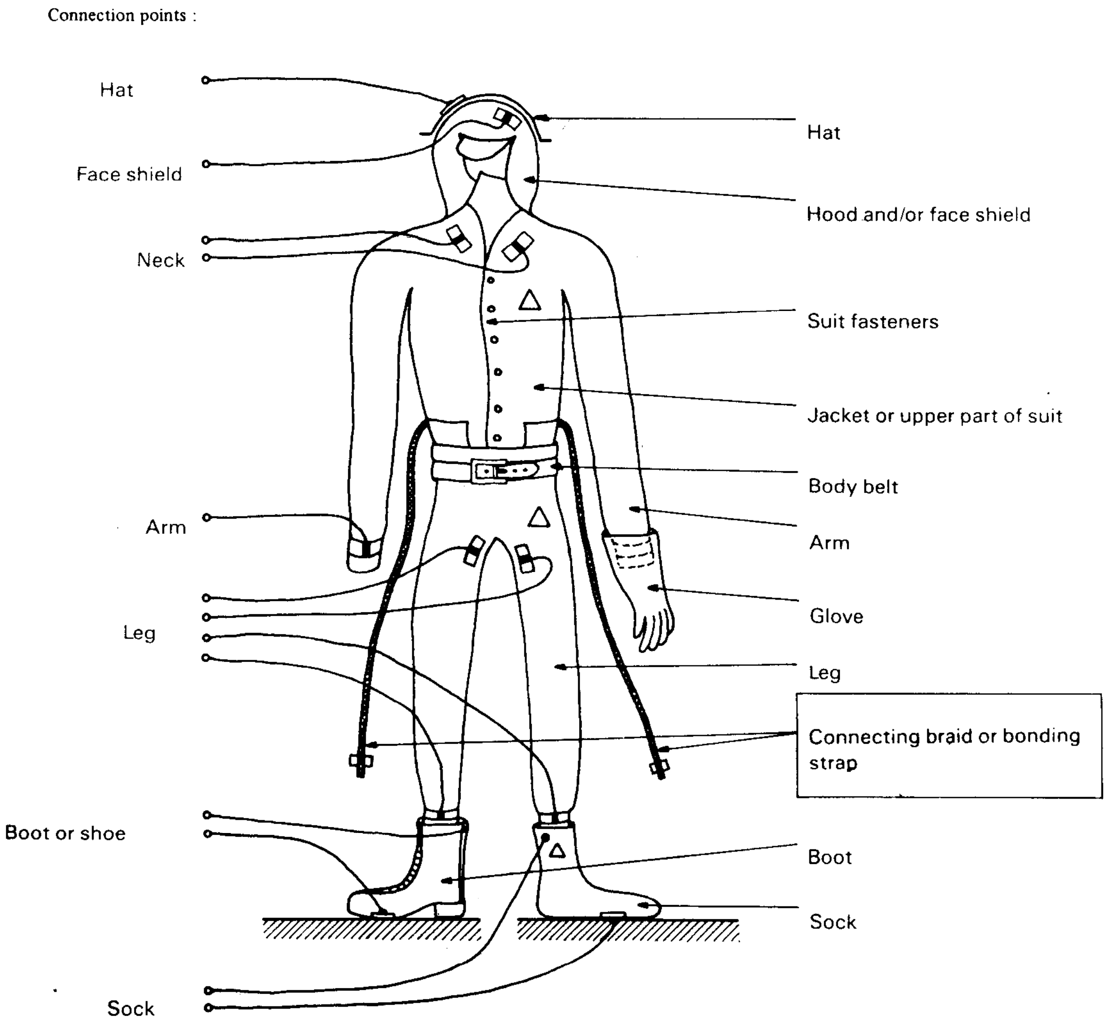


FIGURE C19b

APPENDIX D

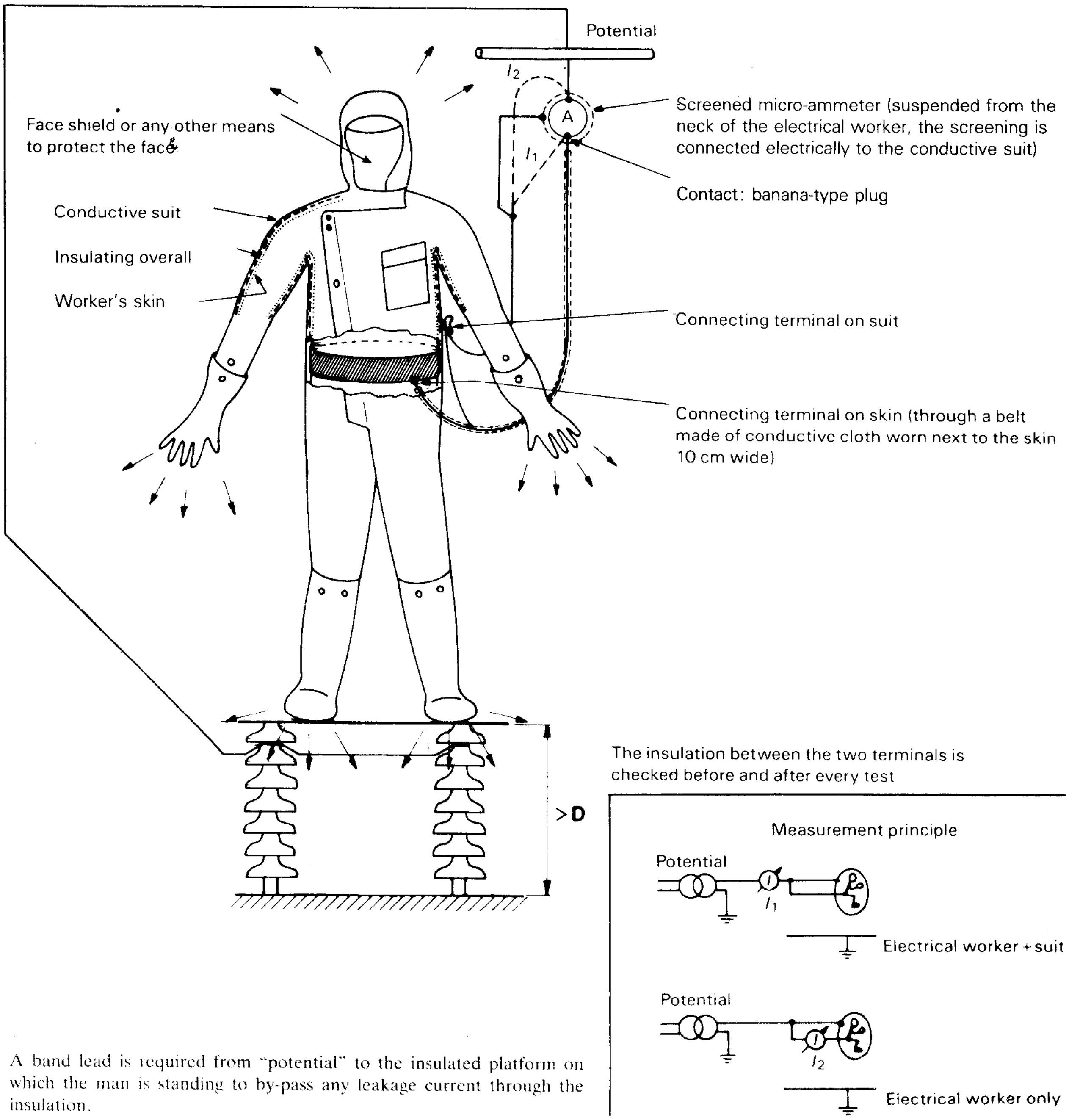
CONDUCTIVE SUIT MEASUREMENT POINTS
(Typical suit construction)



APPENDIX E

MEASUREMENT OF THE EFFICIENCY OF THE ELECTROSTATIC SCREEN COMPLETE SUIT

Position for measuring I_1:
The current measured is the total charging current, it is the current to which the electrical worker would be exposed if he were not wearing a conductive suit.
Position for measuring I_2:
The charging current of the conductive suit by-passes the micro-ammeter and the current measured is that which passes into the electrical worker only.


Potential
I_2
A
I_1
Face shield or any other means to protect the face
Conductive suit
Insulating overall
Worker's skin
Screened micro-ammeter (suspended from the neck of the electrical worker, the screening is connected electrically to the conductive suit)
Contact: banana-type plug
Connecting terminal on suit
Connecting terminal on skin (through a belt made of conductive cloth worn next to the skin 10 cm wide)
>D
Measurement principle
Potential
I_1
Electrical worker + suit
Potential
I_2
Electrical worker only

The insulation between the two terminals is checked before and after every test

A band lead is required from "potential" to the insulated platform on which the man is standing to by-pass any leakage current through the insulation.

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